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TITLE: **AIR MOMENTUM GAGE FOR CONTROLLING NONWOVEN PROCESSES**

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AIR MOMENTUM GAGE FOR CONTROLLING NONWOVEN PROCESSES

BACKGROUND OF THE INVENTION

The present invention relates to an apparatus and process for forming meltspun fibers. More specifically, the present invention relates to an apparatus and process for forming meltspun fibers utilizing a measured velocity, or momentum, profile of the air stream, or jet, used in the making and deposition of meltspun thermoplastic filaments.

Meltspun fibers are fibers formed by extruding a molten thermoplastic material through a plurality of fine, usually circular, die capillaries as molten threads or filaments, and typically into converging, usually hot and high velocity, gas, e.g. air, streams to attenuate the filaments of molten thermoplastic material and form fibers. "Meltspun" fibers, as used herein, may include meltblown fibers or spunbond fibers or the like such as are known in the art. During the meltspinning process, the diameter of the molten filaments may be reduced by the drawing air to a desired size. Thereafter, the meltspun fibers may be further carried by the high velocity gas stream to be deposited on a collecting surface, or forming wire, to form a web of randomly dispersed thermoplastic fibers. Such a process is disclosed, for example, in U.S. Patent Nos. 3,849,241 to Butin et al., 4,526,733 to Lau, and 5,160,746 to Dodge, II et al.

In a conventional meltspinning process, molten polymer is provided to a die that is disposed between a pair of air plates that form a primary air nozzle. Standard meltspun equipment includes a die tip with a single row of capillaries along a knife edge. Typical die tips have approximately 30 capillary exit holes per linear inch of die width and may, e.g. be 200 inches wide. Uniformity of air flow is important in the fiber, and resultant nonwoven fabric, making processes, and yet may be hard to achieve over such widths. The die tip is typically a 60 degree wedge-shaped block converging at the knife edge at the point where the capillaries are located. The air plates in many known meltspinning nozzles are mounted in a recessed configuration such that the tip of the die is set back from the primary air nozzle. However, air plates in some nozzles are mounted in a flush configuration with the same horizontal plane as the die tip; and in other nozzles the die tip extends past the ends of the air plates. Moreover, as disclosed in U.S. Patent No. 5,160,746 to Dodge II et al., more than one air flow stream can be provided for use in the nozzle.

In some known configurations of meltspinning nozzles, hot air is provided through the primary air nozzle formed on each side of the die tip. The hot air heats the die and thus prevents the die from freezing as the molten polymer exits and cools. In this way the die is prevented from becoming clogged with solidifying polymer. The hot air also draws, or attenuates, the melt into fibers via a jet of hot air beginning at about the die tip and expanding conically outward therefrom in all directions. Other schemes for preventing freezing of the die, such as that detailed in

U.S. Patent No. 5,196,207 to Koenig, using heated gas to maintain polymer temperature in the reservoir, are also known. Secondary, or quenching, air at temperatures above ambient is known to be provided through the die head, as in U.S. Patent No. 6,001,303 to Haynes et al.

Primary hot air flow rates typically range from about 20 to 24 standard cubic feet per minute per inch of die width (SCFM/in). Primary air pressure typically ranges from 5 to 10 pounds per square inch gauge (psig) at a point in the die head just prior to exit. Primary air temperature typically ranges from 450 degrees to 600 degrees Fahrenheit (F), but temperatures of 750 degrees F are not uncommon. The particular temperature of the primary hot air flow will depend on the particular polymer being drawn as well as other characteristics desired in the meltspun web.

Expressed in terms of the amount of polymer material flowing per inch of the die per unit of time, polymer throughput is typically 0.5 to 1.25 grams per hole per minute (ghm). Thus, for a die having 30 holes per inch, polymer throughput is typically about 2 to 5 lbs/inch/hour (PIH). Moreover, in order to form meltspun fibers from an input of about five pounds per inch per hour of the polymer melt, about one hundred pounds per inch per hour of hot air is required to draw or attenuate the melt into discrete fibers. This drawing air should be heated to a temperature on the order of 400-600 degrees F in order to maintain proper heat to the die tip.

Because such high temperatures must be used, a substantial amount of heat is typically removed from the fibers in order to quench, or solidify, the fibers

leaving the die orifice. Cold gases, such as air, have been used to accelerate cooling and solidification of the meltspun fibers. In particular, in U.S. Patent No. 5,075,068 to Milligan et al. and U.S. Patent No. 5,080,569 to Gubernick et al., secondary air flowing in a cross-flow perpendicular, or 90 degrees, direction relative to the direction of fiber elongation, has been used to quench meltspun fibers and produce smaller diameter fibers. In addition, U.S. Patent No. 5,607,701 to Allen et al., uses a cooler pressurized quench air said to result in faster cooling and solidification of the fibers. In U.S. Patent No. 4,112,159 to Pall, a cold air flow is used to attenuate the fibers when it is desired to decrease the attenuation of the fibers.

Through the control of air and die tip temperatures, air pressure, and polymer feed rate, the diameter of the fiber formed during the meltspun process may be regulated. For example, typical meltblown polypropylene fibers have a diameter of 3 to 4 microns.

After cooling, the fibers are collected to form a nonwoven web. In particular, the fibers are collected on a forming web, or wire, that comprises a moving mesh screen or belt located below the die tip. In order to provide enough space beneath the die tip for fiber forming, attenuation and cooling, forming distances of at least about 8 to 12 inches are typically required between the polymer die tip and the top of the mesh screen are required in the typical meltspinning process. However, forming distances as low as 4 inches are described in U.S. Patent No. 4,526,733 to Lau or U.S. Patent No. 6,001,303 to Haynes, et al.

All of the above factors may effect the fiber formation and deposition of the fibers on the forming wire and hence, a resultant web made from the fibers. In some cases, undesirable or unusable fibers or webs may result from fluctuations, or non-uniformities, in air flow velocity, especially across the width of the die. In order to derive knowledge about the fiber formation and deposition in an effort to control the processes and identify the source of any problems therein, it is useful to have an air flow velocity monitoring and data gathering means to identify or eliminate air flow velocity non-uniformities as a source of the problems. Past efforts at monitoring and controlling the air flow velocity used in the meltspun fiber making processes have focused on the use of a pitot tube to sense the air velocity. However, the position and placement of a pitot tube in the meltspun air stream must be very carefully controlled to derive useful information related to the meltspun process. It would be highly desirably to have a means of monitoring and controlling the meltspun fiber formation process which is less sensitive to placement and is easily and economically utilized.

SUMMARY OF THE INVENTION

The present invention provides a method for monitoring the air momentum, or velocity, profile of a meltspun fiber formation process and for using the data gained from the monitoring to more effectively produce meltspun fibers and nonwovens webs made from the meltspun fibers.

The apparatus for practicing the method is both economical and easily fitted to existing meltspun fiber apparatus, or in some aspects of the invention may be

hand-held. Further, the apparatus is not position-sensitive within the air stream and will provide accurate flowfield measurements and an integrated velocity profile at any position within the air stream, as will be understood from the law of Conservation of Momentum, such as set forth in *Boundary Layer Theory*, by Dr. Hermann Schlichting, McGraw Hill, 1951, p 732.

In essence, a deflection member, such as a plate or arm, adapted to the meltspun apparatus to be monitored is placed within the jet, or air stream, for producing the filaments, but in the absence of, or prior to, the extrusion of the thermoplastic polymers. The deflection plate is then operably attached to a transducer which in turn provides a read out for information on, and if desired, the control of, the velocity profile of the air stream.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other objects and features of this invention will be better understood from the following detailed description taken in conjunction with the drawings wherein:

Fig. 1 is a top right perspective view of a known meltspun fiber forming apparatus illustrating the environment of the present invention.

Fig. 2 is a schematic representation of a side view, taken along line 2-2 of Fig. 1, of a known meltspun fiber forming apparatus with an embodiment of the present invention in place in operable relationship thereto.

Fig. 3 is a front elevation view of the deflection beam according to an embodiment of the present invention.

Fig. 4 is an end view of the deflection arm of Fig. 3, taken along line 4-4 of Fig. 3, showing the profile of the deflection head which captures the air jet data.

DEFINITIONS

As used herein the term "nonwoven fabric or web" means a web having a structure of individual fibers or threads which are interlaid, but not in an identifiable manner as in a knitted fabric. Nonwoven fabrics or webs have been formed from many meltspinning processes such as for example, meltblowing processes, spunbonding processes, and bonded carded web processes. The basis weight of nonwoven fabrics is usually expressed in ounces of material per square yard (osy) or grams per square meter (gsm) and the fiber diameters useful are usually expressed in microns. (Note that to convert from osy to gsm, multiply osy by 33.91).

The term "meltblown fibers" means fibers formed by extruding a molten thermoplastic material through a plurality of fine, usually circular, die capillaries as molten threads or filaments into converging high velocity heated gas (e.g., air) streams which attenuate the filaments of molten thermoplastic material to reduce their diameter, which may be microfiber diameter. Thereafter, the meltblown fibers are carried by the high velocity gas stream and are deposited on a collecting surface to form a web of randomly dispersed meltblown fibers. Such a process is disclosed for example, in U.S. Patent No. 3,849,241 to Butin et al. Meltblown fibers are

microfibers which may be continuous or discontinuous, are generally smaller than 10 microns in diameter, and are generally self bonding when deposited onto a collecting surface.

"Spunbond fibers" refers to small diameter fibers that are formed by extruding molten thermoplastic material as filaments from a plurality of fine capillaries of a spinneret. Such a process is disclosed in, for example, U.S. Patent No. 3,802,817 to Matsuki et al., U.S. Patent No. 4,340,563 to Appel et al. The fibers may also have shapes such as those described, for example, in U.S. Patent No. 5,277,976 to Hogle et al. which describes fibers with unconventional shapes.

Words of degree, such as "about", "substantially", and the like are used herein in the sense of "at, or nearly at, when given the manufacturing and material tolerances inherent in the stated circumstances" and are used to prevent the unscrupulous infringer from unfairly taking advantage of the invention disclosure where exact or absolute figures are stated as an aid to understanding the invention.

As used herein, the term "machine direction" or MD means the length of a fabric in the direction in which it is produced. The term "cross direction" or "cross machine direction" or CD means the width of fabric, i.e. a direction generally perpendicular to the MD.

DETAILED DESCRIPTION OF THE INVENTION

An embodiment of a known apparatus for forming a meltspun web is shown schematically in Fig. 1 and is represented generally by the numeral 10. As is

conventional, the apparatus includes a reservoir 11 for supplying a quantity of fiber-forming thermoplastic polymer resin to an extruder 12 driven by a motor 13.

The fiber-forming polymer is provided to a melt die apparatus 14 and heated therein by conventional electric heaters (not visible in the view shown). A primary flow of heating fluid, preferably air, is provided to die 14 by a blower 17, which is powered by a motor 18. An auxiliary heater 19 may be provided to bring the primary flow of heating air to higher temperatures on the order of the melting temperature of the polymer.

At the discharge opening of die 14, quenched fibers 20 are formed and collected on a continuous foraminous forming wire screen, or belt 22, into a nonwoven web 24 as the wire 22 moves in a machine direction indicated by the arrow designated by the numeral 26. The fiber forming distance is the distance between the upper surface of the forming wire 22 and the plane of the discharge opening of die 14.

As shown in Fig. 1, the collection of fibers 20 on the forming wire 22 may be aided by a suction box 28. The formed nonwoven web 24 may be compacted or otherwise bonded by rolls 30, 32. The forming wire 22 may be rotated via a driven roll 34.

An embodiment of the fiber forming portion of the meltspun die apparatus 14 looking along line 2-2 of Fig. 1 is shown schematically in Fig. 2. As shown therein, the fiber forming portion 36 of die apparatus 14 includes a die tip 40 that is connected to the die body (not shown) in a conventional manner. Die tip 40 is

formed generally in the shape of a prism that defines a knife edge 21. The knife edge 21 forms the end of the portion of the die tip 40. Die tip 40 is further defined by at least one opposed side surface 42 that intersects in the embodiment shown in Fig. 2 at the horizontal plane perpendicular to knife edge 21. Knife edge 21 at die tip 40 forms the apex of an angle that ranges from about thirty degrees to sixty degrees and allows for formation of a hot air stream, or jet, 57 beginning at the knife edge 21. The airstream, or jet, 57 is formed to carry and attenuate the molten polymer streams. Capillaries (not shown) carrying the molten polymer also exit the fiber forming apparatus 20 the knife edge 21.

Referencing Figs. 1 and 2, an air jet momentum measuring device 51 is mounted on the die 14 by a magnetic stand 71 (Fig. 2) and comprises a cantilever arm 53 attached to a mounting means 73 held by the magnetic stand 71. The person having ordinary skill in the art will appreciate that other placement options may be available for the measuring device 51 within a fiber-forming apparatus, such as, e.g. within a fiber draw unit (FDU) which further attenuates the fibers by airflow. Attached at the suspended end of the cantilever beam 53 is a deflection head 59 placed to be in the flow of the air stream 57 (Fig. 2) before fiber formation, i.e. extrusion of the thermoplastic polymer. A transducer 61 is attached to the cantilever beam 53 to record the force placed on the deflection head 59 by the air stream 57, which will be understood by those in the art to be a jet with the primary direction carrying the molten polymers indicated by an arrow 58. The transducer 61 may be

mechanical, optical, or any other sensory apparatus considered desirable for the task, such as strain gauges or force transducers. Connected to the transducer is a dial 63, or other data output means, capable of displaying, or further transmitting, the data acquired from the transducer as to the force placed on the deflection head 59.

Referencing Figs. 3 and 4, the cantilever beam 53 is a flat piece of steel about 0.05 inches thick T, about 1.75 inches wide W and about 7.0 inches long L1, although the dimensions may be varied according to the particular die to be monitored. The exemplary embodiment was sized to accommodate the monitoring in a particular setting of a meltspun die, and sizes may be varied if needed or desired. As seen in Fig. 3, the deflection head 59 is mounted on one end of the cantilever beam 59 and is 2.0 inches long L2 and extends about 1.57 inches downwardly D from the cantilever beam 53. Referencing particularly Fig. 4, an end view of the cantilever beam 53 and deflection head 59 along line 4-4 of Fig. 3, the deflection head is also 1.75 inches wide W and is aerodynamically shaped in a streamlined profile to extend downwardly to a point 65 with the lower half of each side, collectively 67, of the deflection head 59 being radiused R at about 1.75 inches to minimize buffeting of the deflection head 59 within the air stream 57 (Fig. 2).

During operation, one or more of the momentum measuring devices 51 will be placed at several points across the width of the die 14 into the air stream of the free air jet used to propel the meltspun filaments downward towards the wire 22. Because the total momentum of a free air jet remains constant downstream of the jet

source due to the law of Conservation of Momentum, the momentum can be determined by the force imparted on the measuring device 51 placed in the air stream without regard to exacting placement. As the deflection head 59 is moved by the air stream, the attached cantilever beam 53 will record the force through transducer 61 and display the force measured at a read out 63. The data may further be transmitted to additional equipment such as automated feedback controls, or recording devices, or the like.

In particular embodiments, the monitoring may consist of two or more measuring devices. For example, there may be a measuring or monitoring device 51 placed in the air stream to measure flow at each lateral end of the die to help monitor deckle, or edge formation of the web 24, which is a particularly sensitive area of uniform formation of the web and in which a good deal of waste may be eliminated through proper production techniques.

While in the foregoing specification means and method for monitoring air jet momentum in formation of nonwoven webs has been described in relation to certain preferred embodiments thereof, and many details have been set forth for purpose of illustration, it will be apparent to those skilled in the art that the invention is susceptible to additional embodiments and that certain of the details described herein can be varied considerably without departing from the basic principles of the invention.